Journal of ELECTRICAL ENGINEERING, VOL. 57, NO. 3, 2006, 154–160

USING MAS TO SOLVE PRODUCER CUSTOMER TRANSPORT PROBLEMS

Dang Thanh-Tung [*,**] — **Baltazár Frankovič** [*] — **Ivana Budinská** [*]
Ben Flood [***] — **Con Sheahan** [**] — **Dang Bao Lam** [****]

This paper deals with a problem of using multi-agent technology to simulate and resolve the planning problems. Concretely, multi-agent systems (MAS) are used in studying and resolving the optimization problems within the Producer-Customer-Transport (PCT) domain.

K e y w o r d s: MAS, supply chain, optimization, simulation

1 INTRODUCTION

MAS, due to their modularity, autonomy, parallel processing, and other properties, are a suitable tool for studying the behaviour of discrete event systems (DES). Producer-Customer-Transport (PCTs) problems belong to the DES class also, because the behaviour of the system is driven by events that may occur randomly. Each member in PCTs systems is autonomous, with its own strategies and logics for decision making. Each tends to maximize its own aims, often resulting in mutual conflicts. MAS is a method for organising transport and production plans using automated agents, capable of both planning and negotiating with each other. Due to the fact that producers, customers and transporters are autonomous organizations, using MAS to study their mutual behaviour is proposed as a suitable method.

2 PROBLEM FORMULATION

In the PCT domain producers generate some products, customers consume, and transporters deliver these products from the producers to the corresponding customers, according to conditions specified by the concerned customer. A set of products that a customer requires is called an order. An order, in general, includes the number of each product that the customer wants to buy. In addition, a customer might include conditions in an order that the seller must fulfil, for example, deadlines to get all ordered products and rewards or penalties associated with fulfilling the order with respect to these conditions.

Let us assume that there are n producers, m customers and k transporters. There are p different products. An order that each customer posts has the following form: $\{x_1, x_2, , x_p, T_d\}$, where $\forall\, j \in [1,p], x_j$ is the quantity of the j-th product that the customer wishes to buy and T_d is a deadline by which the customer wishes to receive the order.

Each producer is able to manufacture one or several kinds of products. As a consequence, in some cases, a customer might have to buy from different producers to get the desired amount specified in the order. To simplify, let us assume that each producer manufactures a different set of products, although, in the real-world domain, they can compete each other in making the same kinds of products. An original order of each customer is then divided to a number of sub-orders assigned to individually responsible producers. The next assumption is that a set of tasks to manufacture single products, and task structure (relationships or commitments among these tasks) are known and predefined. This information is necessary for each producer's calculation while constructing production plans.

Transporters have to move from one location to another to deliver products to customers. Unlike producers, we assume that transporters are equivalent and they can transport or deliver the same all kinds of products or serve all customers at once. To simplify, only distances among locations are considered for calculation, and these parameters are assumed to be known. All other events like a possibility of car's breakdown, traffic jam, *etc.* are omitted.

Transporters can start distribution only when they receive complete products from producers. For this reason, the transporters' plans depend on the time when producers complete their production.

An event when any customer notifies a new order activates all members involved in this system. On the basis

[*] Institute of Informatics, Slovak Academy of Sciences, Dúbravská 9, 84507, Bratislava, Slovakia, E-mails: {utrrtung, utrrfran, utrrbudi}@savba.sk;
[**] Enterprise Research Center, University of Limerick, Limerick, Ireland,
[***] Center for Telecomunications and Value-Chain-Driven Research, UL, Limerick, Ireland,
[****] Department of Design of Machines and Robots, Hanoi University of Technology, 1 Dai Co Viet str. Hanoi, Vietnam

ISSN 1335-3632

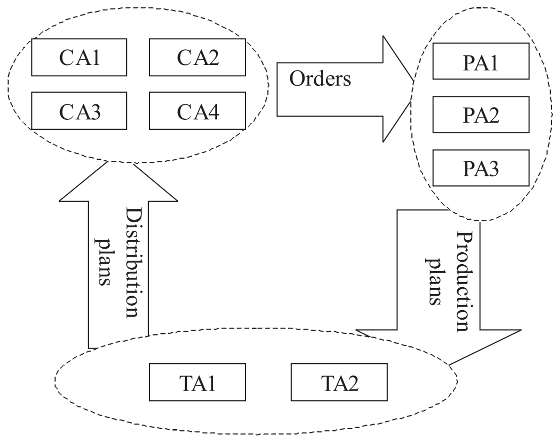

Fig. 1. Basic architecture of PCT systems

of the order's parameters, producers construct a production plan, and afterward contact transporters to prepare a plan for distribution. The main purpose of producers and transporters is to deliver complete orders, with the defined quality and quantity, to a single customer before the deadline that this customer has specified. However, producers and transporters might not be able to fulfil all requirements specified by customers, due to various reasons, such as limited production capacity, limited transporting capacity, short time for order's realization or distribution, or other reasons. In the case of an unfulfilled order, producers and transporters should inform customers about possible changes, and negotiate together with customers to achieve a compromise.

The objective of this paper is to investigate the use of MAS in studying the behaviour of the PCT system, when some new event occurs. The purpose is to observe mutual cooperation among objects, and consequently to derive useful knowledge from the gathered information.

3 BASIC ARCHITECTURE OF MAS USED FOR STUDYING

The basic model consists of three different agent types, namely, producer, customer and transporters agent. Each producer agent (PA) represents one producer (factory, seller,). Its task is to construct a production plan to accomplish all orders as soon as possible. A PA must have complete information about its production resources (that is a common name for all kinds of machines, production lines, *etc.*). In addition, each PA has several default methods for resolving scheduling problems. Based on the customer demands, a PA makes a complete production plan for itself with all information about when ordered products will be completed.

Each transporter agent (TA) represents one transport company, together with all needed information of its transport capacity, speed, *etc.* Its task is to build a distribution plan in order to deliver all ordered products to corresponding customers on time. Similarly to PAs, TAs are able to resolve distribution problems by using default implemented methods. In fact, a distribution plan depends strongly on the time when producers finish single sub-orders. In addition, scheduling problems have usually a huge complexity; as a result, producer agents might tend to achieve only sub-optimal solutions, whose parameters might not be best for calculating distribution plans. For that reason, conflicts often occur between these two group of agents, mainly from a time point of view.

A customer agent (CA) represents a customer, and its task is to generate an order and other associated conditions related to this order.

The MAS structure and interactions among these agents are shown in Figure 1

Interaction cycles among agents are depicted by arrows, where the CAs are the initiators, who invoke all other agents' activities. In the next section, a brief description of the behaviour of each agent will be presented.

4 AGENT BEHAVIOUR

This section describes the default behaviour of each kind of agent implemented in the system. However, concerning the modularity of MAS, each agent might have different behaviour depending on the current situation in the system environment and on its individual goals. Agents influence each because they operate in the same environment. The default behaviour in MAS is based on the assumption that all agents within the system will apply only standard strategies. Mutual influences and interactions among agents will be discussed in Section 5.

4.1 Customer agent (CA)

CA invokes all PAs and TAs activities by specifying a new order. To generate a new order in this model CA uses two. The first method generates a new order at random. The second method assumes that an amount of each kind of products changes according to an approximated function. For an example of the second method, the number of each product in an order is a random variable with a Poisson distribution, but, for each product, the parameters of the Poisson distribution are set differently. The deadline for each order is assumed here to be constant and products need to be delivered to the CA 48 hours after posting an order. However, the parameter 48h might be set differently by each agent. After generating the quantity of each product, CA sends its sub-orders, including the deadline to responsible PAs. If PAs and TAs inform that they are not able to satisfy the order, CA starts to negotiate with them to make a compromise.

4.2 Producer agent (PA)

As has been assumed in Section 2, each PA manufactures different products, so each of them will receive a number of sub-orders from CAs. After receiving all sub-orders, a PA starts to make a production plan. Since task structure to manufacture each product is known, and all information about task execution, including commitments among tasks are predefined as assumed in Section 2, PAs can use some default methods to resolve this scheduling problem. The purpose is to find a production plan that such that all production required is completed in the shortest time possible. Since each sub-order might have a different deadline, PAs often have to deal with each sub-order separately. There are some default strategies for PAs to prepare a production plan.

The first strategy assumes that PA sorts sub-orders according to their deadline. The sub-order with the earliest deadline will be processed first, and so on. Sub-orders that have the same deadline will be taken into consideration as one entity. PA sequentially constructs a production plan for single sub-orders, until there is no sub-orders left in the queue.

The second strategy assumes that PA sorts sub-orders according to their importance. The sub-order's importance is defined by the benefit that PA can receive, as follows. $W_{sub-order} = x_1 v_1 + x_2 v_2 + \; + x_r v_r$, where $W_{sub-order}$ is a weight that PA evaluates this sub-order, $x_1, \ldots, x_r$ are amounts of products that a customer wants to buy from the concerned PA, and $v_1, \ldots, v_r$ are expected profits for a single product unit. Sub-orders with the highest importance according to the above measure will be processed first, and so on. Sub-orders with the same importance will be taken into consideration as one entity.

The third strategy assumes that PA takes into consideration all sub-orders at once and builds a general production plan for them. If the final plan does not allow TAs to finish their distribution in time, for example, if some customers will receive products after their specified deadline, PA will make corrections. To repair a production plan, PA reduces some sub-orders on the basis of their deadline, or their importance. PA could also reduce all sub-orders by the same quantity or percentage. The method for making this reduction is selected on the basis of the agreement among PA and all related CAs; and it will be discussed in Section 5.3.

After completing a production plan PAs inform TAs about the final time that all products are available. These parameters are necessary for TAs to calculate a distribution plan.

4.3 Transporters agent (TA)

On the basis of the information provided by PAs, TAs can prepare their distribution plans. The main constraints are the deadlines specified by customers. As the first aim, distribution plans have to satisfy these predefined constraints. Also, TAs have to request that PAs correct their production plans in order to keep all deadlines. Besides keeping deadlines, TAs should have to make such a plan, so that their vehicles will move as little as possible. The resolution of distribution problems with dynamic deadlines is discussed in several our papers. Only the most important aspects of the behaviour of TAs is discussed here.

First, TAs are autonomous objects, so to decrease redundant work they could agree about a method of dividing their work: (1) each of them is responsible for a separate set of customers, or (2) each of them is responsible for a separate set of products and their delivery to the corresponding customers. In the first case, a distribution plan depends essentially on locations where customers settle; therefore, before requiring PAs to modify production plans, TAs could try to change their customer lists and repeat the calculation. In the second case, a distribution plan depends on the time when single sub-orders are terminated. Similarly, TAs could try to change their list of products in order to satisfy all time requirements. After a certain number of changes, if the time requirements cannot be satisfied, TAs ask PAs to correct their production plans.

Second, TAs usually have to collect products from a number of different producers. In general, these sub-orders are terminated at different times, but a distribution plan depends only on the last time. For this reason, when deadline conditions cannot be satisfied, TAs focus attention mainly on the sub-orders that are latest terminated. The PAs responsible for these sub-orders are then asked to correct their plans.

If TAs are equivalent, each TA could take an amount of products and deliver them to customers. Therefore, they could also cooperate together to improve distribution plans. TAs might apply different manners to distribute work, or share means of transport to achieve more effective plans. All these things will be discussed in the next section.

5 THE USE OF MAS IN THE PCT DOMAI

This section presents a use of MAS in studying the behaviour of individual objects involved in the PCT domain.

5.1 MAS used for simulation

The first purpose of using MAS in the PCT domain is to simulate the behaviour of the whole system. After setting up necessary inputs, agents are automatically activated and interact one with another cooperatively. Simulation helps human managers to better understand and observe the running of the system in reality. Simulation shows when and in which situations agents will interact with each other. Plans are simulated before their realization, so that human managers can verify whether the constructed plans will work well or not.

5.2 MAS used for solving optimization problems

v Each agent works on the behalf of one object. An agent is implemented with all features characterizing the object it is concerned with. On the basis of the given features, agents calculate plans for the producers and transporters. Besides using default methods for solving scheduling and distribution problems, agents can achieve better solutions through cooperation among PAs-TAs or TAs themselves.

One of the methods to improve distribution plans is to make TAs cooperate. When TAs are responsible for a separate set of customers, they try different ways of distributing customers, in order to find as good a plan as possible. In the beginning, customers are distributed to separate groups according to their locations; customers who settle in near locations one to another, are in the same group. Each TA is responsible for one customer group. When any TA has problems with keeping deadline conditions, it asks other agents to take some of its customers to accommodate the current distribution plan. The first TAs to send request are the ones that operate in neighbouring areas. If there is no improvement, TAs repeat distribution of customers according to their location again, but the TAs that can not keep deadline conditions now get fewer customers.

When TAs are responsible for separate sets of products, they try different product distributions to find the best plan. Products are divided into groups according to the amount ordered by customers, considering the location of each customer.

TAs cooperate one with another during the search for an optimal schedule. Agents exchange information about their current plans in order to have a better overview for problem solving. Re-distribution of customers or products could also be made during problem solving within a framework of several agents. Another manner of cooperation is to share means of transport. Several TAs share their vehicles and calculate distribution plans as one entity. In our model, local cooperation is preferred because of the high complexity of the scheduling problem.

TAs cooperate with PAs. To improve a distribution plan, TAs try to ask PAs to change the sequence of the sub-orders' execution. To simplify PA calculations, TA specifies which sub-orders are easiest to complete. Cooperation is performed in three ways: one TA with many PAs; many TAs with one PA; or many TAs with many PAs. Each TA can initiate and ask other agents (transporters or producers) to cooperate. Since personal requirements are not considered, all agents participate in cooperation to improve the collective performance. This cooperation is the second use of MAS in the PCT domain.

5.3 MAS used for solving optimization problems

From a time point of view, conflict situations often occur among PAs and TAs. The main reason is that customers cannot receive the ordered goods on time. Because this problem relates to multiple producers or transporters, negotiation is required to find a solution.

To approximate real-world situations, all agents are implemented with a capability of carrying negotiation. To resolve timing conflicts when a customer cannot get the order in time, TAs and PAs, whose performance is associated with the concerned customer need to cooperate with the corresponding CA to find a solution.

Negotiation is conducted iteratively. In each iteration, TAs send PAs a proposal, which includes timing requirements for selected sub-orders. PAs modify their production plans in order to fulfil the TAs' requirements. Modifications will change the completion time of other sub-orders, and consequently they affect all TAs' plans too. After a specified number of iterations, if TAs and PAs cannot find an appropriate plans to fulfil the customers' time requirements, PAs can ask some CAs to reduce the ordered quantity.

There are many different methods to decide which CAs to ask to reduce their orders. In addition, CAs can reduce the orders in many ways. In our model, some simple methods are implemented, but future research will incorporate more detailed methods. The first method we have implemented assumes that all CAs must reduce their orders, and that all CAs are asked to reduce their orders by the same amount. In each iteration, the reduced amount increases by a constant, until PAs and TAs achieve suitable plans. The second method assumes that CAs are selected to make reduction on the basis of the order's volume. CAs with the order larger than a predefined bound must reduce their order. The predefined bound sequentially decreases, in each iteration, until the PAs and TAs achieve suitable plans. The next implemented method is based on the assumption that CAs reduce their orders of products that have least profits and focus only on the products with high expected benefit. The amount ordered of the selected products decreases by a constant in each iteration. The set of initially selected lower-profit products can be expanded until all agents achieve suitable plans. Agents work automatically and contact one another according to their needs of cooperation, without the intervention of human managers. The final solution, using this MAS, should satisfy all participators' requirements and be without conflicts.

From a time point of view, conflict situations often occur among PAs and TAs. The main reason is that customers cannot receive the ordered goods on time. Because this problem relates to multiple producers or transporters, negotiation is required to find a solution. To approximate real-world situations, all agents are implemented with a capability of carrying negotiation. To resolve timing conflicts when a customer cannot get the order in time, TAs and PAs, whose performance is associated with the concerned customer need to cooperate with the corresponding CA to find a solution. Negotiation is conducted iteratively. In each iteration, TAs send PAs a proposal, which includes timing requirements for selected sub-orders. PAs modify their production plans in order to fulfil the TAs' requirements. Modifications will change the completion time of other sub-orders, and consequently they affect all TAs' plans too. After a specified number of iterations, if TAs and PAs cannot find an appropriate plans to fulfil the customers' time requirements, PAs can ask some CAs to reduce the ordered quantity. There are many different methods to decide which CAs to ask

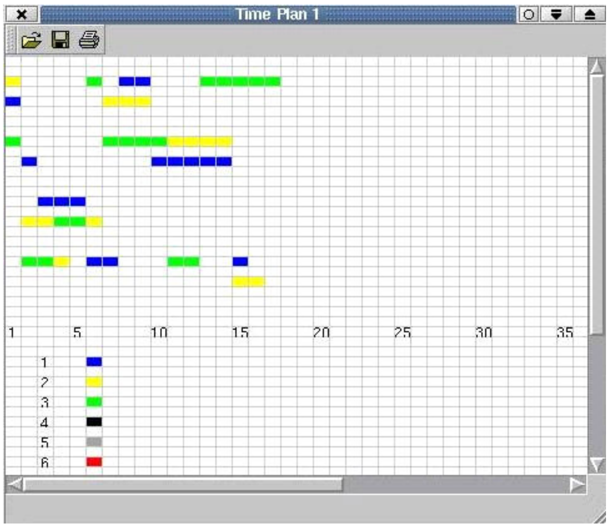

Fig. 2. Output of one PA a complete plan (in case with 4 products)

to reduce their orders. In addition, CAs can reduce the orders in many ways. In our model, some simple methods are implemented, but future research will incorporate more detailed methods. The first method we have implemented assumes that all CAs must reduce their orders, and that all CAs are asked to reduce their orders by the same amount. In each iteration, the reduced amount increases by a constant, until PAs and TAs achieve suitable plans. The second method assumes that CAs are selected to make reduction on the basis of the order's volume. CAs with the order larger than a predefined bound must reduce their order. The predefined bound sequentially decreases, in each iteration, until the PAs and TAs achieve suitable plans. The next implemented method is based on the assumption that CAs reduce their orders of products that have least profits and focus only on the products with high expected benefit. The amount ordered of the selected products decreases by a constant in each iteration. The set of initially selected lower-profit products can be expanded until all agents achieve suitable plans.

Agents work automatically and contact one another according to their needs of cooperation, without the intervention of human managers. The final solution, using this MAS, should satisfy all participators' requirements and be without conflicts.

5.4 MAS used to verify the robustness

Due to the limited capacity of each producer and transporter, all customer orders cannot always be satisfied at once. To investigate the capabilities of producers and transporters to respond to unexpected events in practice, CAs can generate a number of random orders and send them to PAs and TAs. Based on the achieved results, PAs and TAs will maintain approximate knowledge about their own capabilities. This experience helps agents to make quicker decisions when a new situation occurs.

In our experiments, CAs generate sequentially larger orders, until PAs and TAs cannot construct suitable plans for production and distribution. After a number of different combinations of orders, limits of PAs and TAs are specified. Agents are able to appreciate whether they can satisfy these orders by their deadlines.

Agents experiment with various manners of cooperation and negotiation, in order to identify the most appropriate one for some specific classes of situations. TAs experiment with different scenarios in order to determine bottlenecks in distribution plans. This knowledge is very useful, since TAs have usually to resolve distribution problems with similar characters.

5.5 MAS used to extract new trends or knowledge in the PCT domain

Each agent works on behalf of one object. Its simulated behaviour approximates the behaviour of this object in reality. If agents copy the behaviour of these objects exactly, then through simulation it is possible to extract some new knowledge about these objects. For example, when agents have a problem with keeping deadline conditions, by repeating many experiments, it is possible to find out which methods of distributing products to customers are the most often applied and which ones achieve the best results. In other words, simulation results show which customers or products should be in the same group in order to achieve the best plan. Simulation also shows which factors often cause conflicts among agents. For example, large orders of certain products can cause the extension of production plans, which can in turn affect all distribution plans. These products are the first target of reduction if any conflict appears.

It is possible to obtain knowledge about the development of customer demands from a MAS simulation. On the basis of historical orders, CAs approximate the behaviour of the human customers and predict their future demands. Predicted values are very useful for PAs and TAs in material and vehicles preparation. This is one of the most useful aspects of using MAS in studying behaviour of the PCT system.

6 REALIZATION IN PRACTICE AND SIMULATION

Agents are implemented in C++ and PVM. Before starting interactions, all agents have to send register data to the mediator agent. Agents contact each other through the mediator in order to guarantee synchronization. The Internet is used as the medium for communication exchanges. The system has an open architecture, and therefore the number of agents is not limited. Six customers, two transporters and two producers are implemented in the system.

All agents are implemented with default behaviour as presented in Section 4 The system is invoked by whichever CA and the calculation is finished when all agents achieve suitable plans that satisfy customer demands. Each agent can switch among these basic scenarios and experiment

Figure 2 shows a production plan of one PA, which manufactures 4 different products. Figure 3 shows an

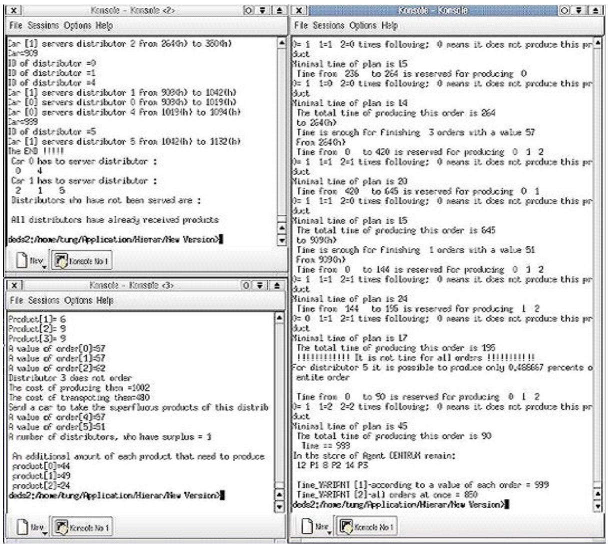

Fig. 3. Output from TAs and PAs calculations

output from TAs and PAs calculation for one specific situation.

Within a framework of experiments, CAs generate different orders by using the methods presented in Section 4.1. CAs use one of the predefined deadlines for each order. Production and distribution plans are then calculated on the basis of these orders.

Simulated results are used to verify the goals presented in Section 5, mainly to verify the robustness of agent capabilities to react to unexpected situations. The different methods for solving scheduling problems have been tested and compared, and these results will be presented in a publication in preparation.

Simulated results lead to a lot of useful knowledge. For example, many customers usually repeat their order many times, and for this reason recording historical plans is useful and helps both the PAs and TAs to save a lot of computation time. Furthermore, on the basis of simulated results, PAs and TAs are able to approximately predict the critical time when CAs bid too much and to try to negotiate with customers in advance of these situations to avoid overloading. For example, it may be possible to ask customers to change the deadline (earlier or later) or to change the ordered volume.

Combining simulated results and real values specified by human managers helps agents to identify more precise mathematical models of customers. CAs approximate the development of customer orders and consequently predict their near future demands, which are then sent to PAs. Based on the estimated orders, PAs make a plan to produce some amount in advance, to avoid critical situations. The real values specified by human managers serve as feedback and help to improve the preciseness of the approximate mathematical customer-model.

Simulation can be used to show many difficulties related to cooperation among agents. The default methods for negotiation always guarantee the existence of a final solution, since all agents have to make compromises according to specified rules. However, human managers might apply various strategies within negotiation. In some experiments, where each agent uses a different strategy for calculation, the agreement is achieved after very long negotiations. Similarly, TAs and PAs can cooperate in many ways; they can share information, production or transportation capacity in different manners, but in the inhomogeneous field, where each of them applies different behaviour, cooperation becomes more complicated and not always brings the benefits they expect. These problems are the subject of future work.

7 COMPARISON WITH SOME RELATED WORKS

MAS are used for a variety of purposes; one of which is studying the behaviour of discrete event systems [1]. There are a number of applications that use MAS technology for that purpose. For example, MAS are used to simulate the behaviour of human beings in critical situations like fire, flood, *etc*[5], [7], [8]. MAS are also used to simulate traffic situations in inner-city telecommunication network [2], [3], [6].

In spite of numerous papers that discuss the use of MAS for simulation and studying, there are only several that deal with PCTs. The closest work to this one may be [9], which differs form this paper in that it considers producers and transporters in competition with another, and does not utilise historical data.

In [9] each order is one subject of an auction in which producers and transporters compete. Producers are equivalent and manufacture the same products. Transporters are also equivalent, and transport the same products and have the same capabilities. Producers and transporters cooperate by joining a common group; and the group that is able to produce at the lowest cost and to deliver in time will be selected as the winner of the auction. The work in [9] focuses more on negotiation and competition among agent groups than on solving the global optimization problem of the PCT system. Our model considers a case study with different character. TAs are always cooperative in order to improve their collective performance. This is appropriate to large distributed enterprises. PAs and TAs work on the same principle. In addition, all agents in this paper, including CAs, take part in the negotiation to find a satisfactory compromise if there are some conflict situations.

Another work with similar character to this paper is [10], in which MAS are used to study supply-chain-management (SCM) systems. Agents work on behalf of individual elements included in the SCM system. Negotiation is only between sellers and buyers (like producers and customers in this paper); however, agents concentrate only on the final benefits and omit the local optimization problems, *ie*, how to manufacture and distribute optimally.

Our model is novel from [9] and [10] in the following ways. The first novelty is the exploitation of MAS simulation in studying and verifying the capability of each element, in identifying their limitations, and consequently in proposing methods to resolve possible critical situations. The second novelty is to exploit simulated results combined with historical data in order to extract new knowledge about each member involved in the PCT system. Using this knowledge allows agents to predict critical situations that might occur in the future and consequently to make suitable plans for their resolution.

8 CONCLUSION

This paper discusses the use of MAS technology in studying PCT systems. MAS are exploited to resolve optimization problems, namely, scheduling and distribution planning, inseparable parts of any PCT system. In addition, MAS are used to resolve some problems on the behalf of human users, for example, implementing automatic negotiation and cooperation to improve the final solution. Besides these, MAS simulation is used to identify useful knowledge about the PCT system behaviour, to identify the robustness of agent capabilities, to identify bottlenecks in the distribution system, and to resolve conflict situations among single agents. MAS simulation helps also to identify the mathematical model of agent behaviour, to predict customers' future demands and to predict critical situations in advance.

Future work will extend Section 6 by using MAS simulation to study inhomogeneous systems, where agents have arbitrary behaviours, and to use MAS simulation to find new knowledge about customers, e.g., new trends of customer interests, *etc.*

Acknowledgement

This work has been funded by the Irish Research Council for Science, Engineering and Technology (IRCSET).

References

[1] www.agentlink.org.

[2] HERNÁNDEZ, J.—OSSOWSKI, S.—GARCÍA-SERRANO, A. : On Multiagent Co-Ordination Architectures: A Traffic Management Case Study, In the proceeding of 34th Annual Hawaii International Conference on System Sciences (HICSS-34)-Volume 3, January 03–06, 2001.

[3] WAHLE, J.—SCHRECKENBERG, M. : A Multi-Agent System for On-Line Simulations Based on Real-World Traffic Data, In the proceeding of 34th Annual Hawaii International Conference on System Sciences (HICSS-34)Volume 3, January 03–06, 2001.

[4] YOUNGER, S. M. : Discrete Agent Simulations of the Effect of Simple Social Structures on the Benefits of Resource Sharing, J. Artificial Societies and Social Simulation **6** No. 3 (2003).

[5] DAL FORNO, A.—MERLONE, U. : A Multi-Agent Simulation Platform for Modeling Perfectly Rational and Bounded-Rational Agents in Organizations, J. Artificial Societies and Social Simulation **5** No. 2 (2002).

[6] TARAG, F.—SUFIAN, Y.—STRANGE, C. : A Study of the Behaviour of the Mobile Agent in the Network Management Systems, PGNet2003. http://www.cms.livjm.ac.uk/pgnet2003/.

[7] ADHICANDRA, I.—PATTINSON, C.—SHAGHOUEI, E. : Using Mobile Agents to Improve Performance of Network Management Operations, PGNet2003. http://www.cms.livjm.ac.uk/pgnet2003/.

[8] MARZO, J.—VILA, P.—FABREGA, L.—MASSAGUER, D. : A Distributed Simulator for Network Resource Management Investigation, In Computer Communications Journal — Special Issue on Recent Advances in Communication Networking. Vol. 26, No. 15, September 2003, Pages 1782–1791.

[9] REGIS, V.—HORLING, B.—LESSER, V. : An Agent Infrastructure to Build and Evaluate Multi-Agent Systems: the Java Agent Framework and Multi-Agent System Simulator, In Lecture Notes in Artificial Intelligence: Infrastructure for Agents, Multi-Agent Systems, and Scalable Multi-Agent Systems., Vol. 1887, January, 2001.

[10] CANTAMESSA, M.—VILLA, A. : Negotiation Models and Production Planning for Virtual Enterprises, In Proceeding of The IFAC Workshop on Manufacturing, Modeling, Management and Control – MIM 2001, Prague, Czech Republic, 1–5.

[11] WELLMAN, M. P. : A Market-Oriented Programming Environment and its Application to Distributed Multicommodity Flow Problems, J. Artificial Intelligence Research **1** (1993), 1–23.

Received 25 October 2005

Dang Thanh-Tung received the Ing (Msc) degree from the Faculty of Electrical Engineering and Informatics, at Slovak Technical University, Bratislava (1997); and PhD degree from Institute of Informatics, SAS (2003). His research interests in MAS, planning and scheduling, reasoning and knowledge management. His current project is using MAS for intelligent manufacturing.

Baltazár Frankovič is a member of IFAC/IFIP TC (technical committee), scientific society ECCAI, SSKI, J.von Neumann Society Budapest. He is a member of the Central European Academy of Sciences and Arts. He acts as a member of the Editorial Board of some current journal, like Journal of Computer and Artificial Intelligence. His current research interests in modelling and simulation of FMS, adaptive and learning control in DEDS, MAS. His publications contain above 5 books, 124 scientific papers.

Ivana Budinská graduated from the Slovak Technical University, Faculty of Electrical Engineering in 1987, and received the PhD degree from Institute of Informatics, SAS, in 2003. Her research interests in DEDS, control theory and MAS.

Ben Flood received a (BSc) degree in Applied Mathematics and Computing in the University of Limerick, Ireland (2002); and PhD degree from the same institute, (2006). His research interests statistical decision theory and mathematical modelling in reliability. His current project is in using Bayesian methods in reliability in the Center for Telecommunications and Value-Chain Research (CTVR), funded by Science Foundation Ireland (SFI).

Con Sheahan received his PhD degree from the University of Limerick in 1996. His research interests on the domain of manufacturing resource optimization, including operations research, discrete mathematics and complexity theory.

Dang Bao-Lam received a MSc degree on Automation in 1998 at Slovak University of Technology, Bratislava, Slovakia and a MSc degree on Mechanics of Machines in 2004 at Hanoi University of Technology, Viet Nam. His research interests on kinematics, dynamics, control and simulation of robotic systems.